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[12] # Description of Invention

for an Inventor's Certificate

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[53]	UDC	622.276 (088.8)
[56]	References Cited:	1. US patent no. 3412792, cl. 166-9, 1968.

[54] Method of crude oil production

[54] Sposob dobychi nefti

[57] Abstract

The invention concerns the oil-producing industry, in particular production methods using flooding. The goal of the invention is to increase the efficiency of the process by increasing the sweep efficiency of the pool. A formation is injected with a dispersion of solid particles in an aqueous solution of a non-ionic surfactant containing a water-soluble polymer in the amount of 0.005-1.0% of the mass of the dispersion. The dispersion of solid particles is a dispersion of water-insoluble salts obtained by mixing water solutions containing precipitate-forming ions. Polyacrylamide or carboxymethyl cellulose is used as the water-soluble polymer. The method allows an additional 150-300 tons of oil to be produced per ton of polymer. 1 dependent claim, 2 tables.

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The invention concerns the oil-producing industry.

The goal of the invention is to increase the efficiency of the process by increasing the sweep efficiency of the pool by flooding.

To implement the method a dispersion of solid particles in an aqueous solution of a surfactant also has a water-soluble polymer introduced into it in the amount of 0.005-1.0% of the total mass of the dispersion.

Polyacrylamide or carboxymethyl cellulose is used as the water-soluble polymer.

The dispersion of solid particles is a dispersion of water-insoluble salts, for example carbonates or sulfates or calcium, barium, strontium, hydroxides or oxides of magnesium, iron, and others, which are obtained by mixing water solutions containing precipitate-forming cations and anions.

The proposed method, which introduces a water-soluble polymer (polyacrylamide and carboxymethyl cellulose) containing the carboxymethyl anion group, into an aqueous solution of the surfactant and the dispersion of solid particles, forms a dispersion of these particles in the solution of surfactant and polymer, which is more stable aggregatively (the association of separate particles in flocs) and kinetically (the speed of separation of the dispersion into a solid and liquid phase) than a dispersion of solid particles produced according to the known method. Such stability of the dispersion is explained by the adsorption of separate flocs of surfactant-containing particles on one molecule of polymer as a result of the formation of a solid chemisorption connection between the surface of the solid salt particle and the carboxymethyl group of the polymer and as a result of the ion-dipole interaction between the surfactant and polymer molecules. The size of the polymer flocs of solid particles formed exceeds the size of those of the solid particles formed as the result of using surfactant only. This ensures that the porous environment of the oil formation captures the polymer-containing flocs more efficiently, and, accordingly, that the flow of injected water is redistributed more efficiently into weakly draining oil-saturated interlayers. In distinction to known oil production methods, the proposed one significantly increases the sweep efficiency of the pool by flooding.

The dispersion ability and stability of the dispersion of solid particles in the aqueous solution of surfactant containing a water-soluble polymer, (the proposed method) and not containing one (the known method), and their efficiency are determined by displacing oil from a heterogeneous model of the formation.

A dispersion of calcium carbonate is used as the dispersion of solid particles. It is obtained by mixing a 0.05% aqueous calcium chloride solution with a 0.05% aqueous sodium carbonate solution in a 1:1 volumetric ratio, or a model of waste water containing (%): calcium chloride 0.195; magnesium chloride 0.013; sodium chloride 0.135; sodium bicarbonate 0.032%, with a 0.025% aqueous solution of calcium carbonate in equal volumes.

For the surfactant, a non-ionic surfactant is used of the brand neonol AF-10 or AF-12 products containing them; the brands SNO-3B or SNO-4D.

For the polymer, polyacrylamide is used having a molecular weight of 10^7 with a degree of hydrolysis of 15% (P-1), polyacrylamide having molecular weight of 15.6 x 10^6 with a degree of hydrolysis of 25% (P-2) and carboxymethyl cellulose.

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The dispersion of solid particles is obtained by mixing equal volumes of aqueous solutions of surfactant containing precipitate-forming cations of calcium (and magnesium in waste water), and polymer containing a precipitate-forming carbonate anion.

The prepared water dispersions of calcium carbonate (and magnesium carbonate in waste water) contain (with magnesium carbonate in waste water), in mass percent: $CaCO_3$ 0.05-0.1; surfactant 0.005-0.5; polymer 0.001-1.0.

Example 1. Investigation of the dispersion ability and stability of the prepared dispersions over time. The stability is evaluated by the change in optical density (OD) of the prepared dispersions over time. The optical density is determined on a KFK-2 photoelectric colorimeter at a wavelength of 590 nm and a cell length of 50.0 mm at room temperature.

Table 1 gives the results of the investigation of dispersion ability and stability in the form OD_{max} and $OD(\tau)$ over time. The greater OD_{max}, the greater the size of the precipitate particles; and the longer the optical density (OD) is preserved, the higher the stability of the dispersion.

The dispersion and stability of solid particles in water is less than in surfactant solution (experiments 1 and 10 compared with 2 and 9). However, introducing into the dispersion particles in surfactant ~~and~~ polymer solution in the amount of 0.005-1.0% sharply increases the dispersion ability and stability of the dispersion of solid particles in aqueous surfactant solution (experiments 4-6 compared with experiment 2, experiment 8 compared with experiment 9, and experiments 11 and 13 compared with experiment 2). The minimum polymer content in the dispersion which ensures that it has a high dispersion ability and stability is 0.005 mass % (experiments 2 and 3 compared with experiment 4), and the maximum content is 1.0 mass %, since that is the polymer content which produces the maximum stability of the dispersion in water (experiment 11).

Thus, the polymer content in a stable dispersion of solid particles in aqueous surfactant solution is 0.005-1.0 mass %.

The polymer alone (without surfactant) does not ensure maximum stability and dispersion ability of the solid particles in water (experiment 6 compared with 7, 11, and 12).

Example 2. The efficiency of the proposed method and the known method are determined by filtering a dispersion of solid particles through homogeneous water- and oil-saturated models of the formation represented by polymictic sandstone, 27 cm long, 1.1 cm in diameter, and having a permeability of 5-5.5 μm^2. The water-saturated model is prepared by injecting three pore volumes of water with a total salt content of 1.58% under constant pressure until there is outflow at a steady state of filtration, and the filtration time per unit water is determined. The oil-saturated model is prepared like the water-saturated one, but then it is also injected with oil having a viscosity of 8.9 mPa at 20° C until it reaches its irreducible residual water saturation. The experiments are conducted at 65° C.

The core is injected, until it reaches a steady state of filtration, with around three pore volumes of the investigated dispersion of calcium carbonate in an aqueous solution of surfactant according to the known method or in an aqueous solution of surfactant and polymer according to the proposed method, or an aqueous solution of polymer having the same concentration as in the investigated dispersion according to the known method (without precipitate), and the filtration time is recorded per unit volume of injected liquid.

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The flow resistance factor is determined for the filtration of each fluid in the water- (w) and oil-saturated (o) cores according to the formula:

$$R^{w,o}_{surf., disp., polym.} = \frac{\tau^{w,o}_{surf., disp., polym.}}{\tau_w}$$

where $\tau_{surf.}$, $\tau_{disp.}$, and $\tau_{polym.}$ are the filtration time of the surfactant, dispersion, and polymer, respectively. The control capability (CC), or the dependence of the formation's sweep efficiency n_{sweep} on flooding by injecting the investigated compositions according to this or that procedure is evaluated according to the relationship:

$$CC\ (v_{sweep}) = \frac{R^{w}_{surf., disp., polym.}}{R^{o}_{surf. disp., polym.}}$$

The higher this indicator, the more efficient the method is.

Table 2 shows the results of the experiments. The proposed method is more efficient than the known method and the method of polymer flooding, both according to the flow resistance factor and according to sweep efficiency (experiments 1 and 2 compared with experiments 3-6, experiments 7 and 8 compared with experiments 9-12, and experiments 13 and 14 compared with experiments 15-18).

Thus, the proposed method of producing oil is more efficient than known methods due to the more efficient redistribution of the injected liquids from the water- and oil-saturated interlayers, and consequently, as a result of the increase in the sweep efficiency of the pool due to flooding.

The proposed method is used to increase the oil recovery of the formations by flooding it in two variants.

According to the first variant, when the oil field is developed by injecting it with fresh water, and the water line is sequentially dosed with polymer, surfactant, and concentrated aqueous solutions of salts (bases and acids) forming an insoluble precipitate between one another or with formation water, and the prepared dispersion is injected into the formation.

According to the second variant, when the oil field is developed by means of injecting waste water containing suspended particles and oil from the crude oil treatment plants, or by mixing them with fresh water, the water line with this water is dosed with polymer and surfactant at a rate to produce a 0.005-1.0% solution of them in the injected water.

Compared with the known method, the proposed method of oil displacement allows an additional 150-300 tons of oil to be produced for each 1 ton of polymer used.

Claims

1. Method of producing oil, comprising injecting into the formation a dispersion of solid particles in an aqueous surfactant solution, **characterized by the fact** that in order to increase the efficiency of the method as a result of increasing the sweep efficiency of the formation

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by flooding, the dispersion of solid particles in surfactant solution also contains a water-soluble polymer in the amount of 0.005-1.0% of the total mass of the dispersion.

2. Method according to Claim 1, **characterized by the fact** that polyacrylamide or carboxymethyl cellulose is used as the water-soluble polymer.

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Table 1

Exp.	Content of components in dispersion, mass %					OD_{max}	OD (τ)	at τ	min.
	$CaCO_3$	Surfactant		Polymer			30	60	90
		Brand	Qty	No.	Qty				
1	0.1	—	—	—	—	0.17	0.10	0.10	0.10
2	0.1	AF-10	0.5	—	—	0.75	0.35	0.20	0.15
3	0.1	AF-10	0.5	P-1	0.001	0.80	0.40	0.25	0.25
4	0.1	AF-10	0.5	P-1	0.005	1.20	0.6	1.2	1.05
5	0.1	AF-10	0.5	P-1	0.01	1.35	0.7	1.35	1.2
6	0.1	AF-10	0.5	P-1	0.05	1.70	1.5	1.7	1.7
7	0.1	—	—	P-1	0.05	1.60	1.4	1.3	1.3
8	0.05	AF-12	0.005	P-2	0.01	1.55	1.25	0.85	0.55
9	0.05	AF-12	0.005	—	—	0.80	0.35	0.20	0.15
10	0.05	—	—	—	—	0.30	0.1	0.1	0.1
11	0.05	[?]	0.5	CMC	1.0	1.6	1.6	1.6	1.6
12	0.05	—	—	CMC	1.0	1.1	1.0	0.9	0.7
13	0.05	—	0.5	CMC	0.5	1.4	1.3	1.1	0.8

Table 2

Exp.	Method.	Type of model	Content of components in dispersion (mass %)					R[?]	CC
			$CaCO_3$	Surfactant		Polymer			(?
				Brand	Qty	No.	Qty		
1	Proposed	w	0.1	AF-12	0.5	P-2	0.01	4.0	1.9
2	Proposed	o	0.1	AF-12	0.5	P-2	0.01	2.01	
3	Known	w	0.1	AF-12	0.5	—	—	1.7	
4	Known	o	0.1	AF-12	0.5	—	—	1.5	1.1
5	Polymer flooding	w	—	—	—	P-2	0.01	2.9	
6	Polymer flooding	o	—	—	—	P-2	0.01	1.9	1.5
7	Proposed	w	0.05	AF-12	0.5	CMC	1.0	3.1	1.8
8	Proposed	o	0.05	AF-12	0.5	CMC	1.0	1.7	
9	Known	w	0.05	AF-12	0.5	—	—	1.3	1.1
10	Known	o	0.05	AF-12	0.5	—	—	1.2	
11	Polymer flooding	w	—	—	—	- " -	1.0	1.3	1.2
12	Polymer flooding	o	—	—	—	- " -	1.0	1.1	
13	Proposed	w	0.1	AF-10	0.005	P-1	0.05	3.5	1.8
14	Proposed	o	0.1	AF-10	0.005	P-1	0.05	1.9	
15	Known	w	0.1	AF-10	0.005	—	—	1.0	1.0
16	Known	o	0.1	AF-10	0.005	—	—	1.0	
17	Polymer flooding	w	—	—	—	P-1	0.05	2.1	1.5
18	Polymer flooding	o	—	—	—	P-1	0.05	1.4	

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